

HARNACK

**The Development and Economy
of Timber Preservation**

Civil Engineering

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**THE DEVELOPMENT AND ECONOMY OF
TIMBER PRESERVATION**

BY

GEORGE A HARNACK

T H E S I S

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

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May 24, 1912

This is to certify that the thesis of GEORGE A HARNACK
entitled THE DEVELOPMENT AND ECONOMY OF TIMBER PRESERVATION was
prepared under my personal supervision; and I recommend that it
be approved as meeting this part of the requirements for the de-
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INTRODUCTION

In view of the steadily decreasing supply of timber suitable for structural and railroad purposes, the subject of wood preservation is one which should engage the attention of every engineer. It is a well-known fact that, at the present rate of consumption, in a few years time there will no longer be a dependable supply of many species of timber. We must then find some way to make these species more durable and to utilize the inferior varieties. This problem is being solved by the modern processes for the preservative treatment of timber.

It is the object of this thesis to show the importance of this subject, giving an idea of the amount of timber used, the causes of decay and the purpose of the various treatments. The development of the different methods of preserving will be traced from the earliest times; showing the difficulties that have been overcome and the relative advancement in the last few years. A general description of the processes most widely used at present will be given. These are creosote, zinc-chloride, zinc-tannin and zinc-creosote and other processes used under pressure for preserving ties, piles, and bridge timbers; and the open-tank processes used for preserving poles, piles, cross-arms and mine-timbers.

In conclusion, the relative cost of treated and untreated timber will be taken up, showing under what conditions the different processes are most economical, and a discussion given of other considerations for and against the preservative treatment of timber.

THE NEED FOR TIMBER PRESERVATION.

There have been so much discussion and quotation of statistics on forestry during the past few years, that everyone realizes that our forests are fast disappearing. The engineer now finds many places where metal is more economical than wood, due to the high price of the latter material. The average cost of timber increased from \$11.13 to \$15.37 per thousand feet B.M. in the period from 1900 to 1908.* This amounts to a rise in price of practically 40 per cent. Although prices are rising, the rate of consumption seems to advance even faster. In 1909 we were cutting timber three times as fast as it was growing and the available supply had decreased from an original acreage of 850 million to 550 million acres.° It is evident that this condition can not continue indefinitely.

A great deal of this timber is wasted because its full efficiency is not realized. For many years it was cheaper to allow ties and structural timber to rot out, requiring comparatively frequent replacement, rather than to treat them by some antiseptic process, thereby greatly prolonging their life. These conditions are changing, however; inferior species of timber are now being utilized through treating processes and the life of the better grade is prolonged. The engineer is finding that, although preservative treatment increases the first cost, it greatly decreases the total cost in most cases.

*C. P. Winslow - U. S. Forest Service.

°Forest Circular 166.

CAUSES AND REMEDIES FOR THE DESTRUCTION OF TIMBER.

The destruction of timber used in engineering work is due to two active agents, decay and marine wood-borers. Destruction by decay is the more important of the two.

It is a favorable combination of the four factors, moisture, heat, air, and food, which causes timber to decay. It is a well known fact that timber which remains under water, being deprived of air, lasts forever; but rots if exposed for even a short time. The direct cause of decay is the growth of fungi, - minute plants which grow in the fiber of the wood. As Dr. Herman von Schrenk* expresses it, "Decay is a chemical process induced by ferments given off by the threads of low plants growing in the wood." The plates show the manner in which certain kinds of these fungi attack cross-ties. Spores or ferments are given off from these growths, and start decay in other ties.

In ocean waters, the greatest enemies of timber are certain species of marine borers, the Teredo and Xylotrya being the most important. These organisms commonly known as "shipworms", bore into piles below the low water mark and honey-comb the interior until it finally breaks off. As the entrance is below low water, there are no surface signs of the ravages of the worm, and the pile may be in a dangerous condition although it is apparently sound. These worms thrive best in warm waters and although certain species have been found in Maine, they are "most destructive from Chesapeake Bay south to Florida, on the Gulf of Mexico, and along the entire

*Railway Age, March 15, 1901.

Pacific Coast."*

Since it is impossible to exclude moisture, heat and air from timber, the preserving is done by means of some antiseptic treatment which poisons the fiber of the wood which the destroying fungi feed upon. This is the principle used in practically all modern methods of timber preservation.

One must know something of the structure of wood before the process of preserving can be made clear. Timber is formed of longitudinal fibers which are simply rows of cells. These cells are filled with water in the form of sap, and there is also sap between the fibers. In most preserving processes this sap is extracted by vacuum or seasoning, or both, and replaced by the antiseptic fluid forced in under pressure. In some processes the timbers are only steeped in the fluid, or painted with it. These latter are not so reliable as the vacuum-pressure method, since a large amount of water is left in the wood.

As a protection against marine borers, some solution is injected which these animals will not touch and which will not leach out in salt water.

There are two classes of substances used in preserving timber, namely, antiseptic salts and antiseptic oils. Among the salts which have been most commonly used are zinc-chloride, copper-sulphate, and corrosive sublimate. The most common oil used is dead oil of coal tar, or creosote. Combinations of these have also been used, such as zinc-creosote and zinc tannin. Petroleum is

*Circular 128 - U. S. Forest Service.



FIG. 1.—UNTREATED BEECH TIES WITH A TIMBER-DESTROYING FUNGUS (*POLYSTICTUS VERSICOLOR* FR.) GROWING ON THE ENDS—AN EVIDENCE OF DECAY.



FIG. 2.—UNTREATED RED OAK TIES WITH A TIMBER-DESTROYING FUNGUS GROWING ON THEM. ONE TIE IS BADLY SPLIT.



FIG. 1.—UNTREATED HEMLOCK TIES WITH A TIMBER-DESTROYING FUNGUS GROWING ON THEM.

[Note that almost all of these ties have fungi on them.]

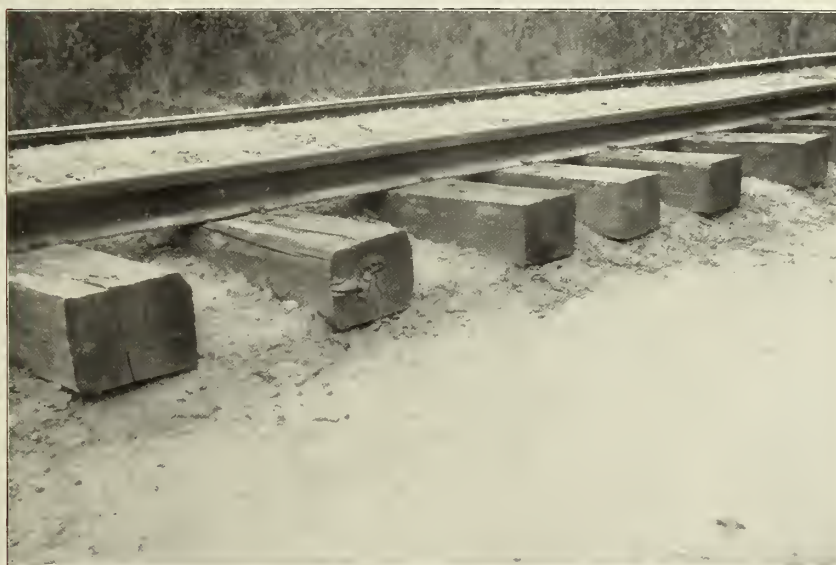


FIG. 2.—UNTREATED LONGLEAF PINE TIES, ONE OF WHICH SHOWS TIMBER-DESTROYING FUNGUS (*LENZITES SEPIARIA*).

also being used to some extent, but it is hardly possible to judge of its success as yet. Another process depends on the injection of live steam which is claimed to coagulate the albumen of the wood, making it proof against the fungi. The efficacy of this treatment has not yet been proven.

DEVELOPMENT OF THE PROCESSES.

Preservation of wood may be said to have been tested as long as the history of man, for piles have been dug from the river Tiber in a perfect state of preservation after at least 2000 years. This is due to the fact that air and light are excluded from the wood-cells by the water. But the commercial development of the preservation of timber is a comparatively recent process and while it may be said to have been begun in 1838, it has only become important in this country in the last fifteen years.

Many processes were tried in early times. "In 1705, Homberg soaked wood in a weak aqua solution of corrosive sublimate. In 1730, Job Baster treated wood with an aqua of corrosive sublimate and arsenic for shipbuilding purposes. In 1740, Reed used wood vinegar. Fagot used alum, iron vitriol and steam. This treatment of Fagot's in 1740 is the first noticed using steam for the preservation of wood. In 1756, Hale treated wood with a solution of tar oil and wood vinegar. About this time the process generally used for preserving wood was to dip it in boiling hot wood tar. In 1756, Jackson used a mixed solution of sea salt, lime, sulphate of zinc, alum, epsom salt ashes and sea water. From 1767 to 1812, the solutions just mentioned were used in a variety of ways. In 1812, coal tar was first used by Cook for the preservation of ships and ship timber. In 1823, Oxford used for the first time oils distilled from tar, applying them to the wood as paint. In 1835, Moll was the first to use the vapors of wood tar and creosote, the

wood being enclosed in tight chambers."*

These experimenters simply boiled ship-timbers in the different substances used. In 1831, Breant, a Frenchman, first used pressure in the preservation of timber. He used a closed vertical cylinder and applied the pressure at the end by means of a force pump. For a preservative, he used sulphate of iron, linseed oil, or a mixture of linseed oil and resin.

In 1852, Kyan patented a process for ^{the} preservation of timber by steeping in a 5 per cent solution of corrosive sublimate. This was found to give good results for structural timber where there was not much moisture to wash out the mineral.^o There was always great danger of salivating the workmen, and the preservative was quite expensive, so the process was only used to a limited extent in America and is not used at all now.

About 1839-46, Dr. Boucherie, a Frenchman, experimented with a number of preservatives and methods of using them. He finally evolved a method of injecting copper sulphate by applying pressure at the ends of freshly cut logs. This method was not a success as there was difficulty in sawing these treated logs and in applying the treatment in or near logging camps.

Modern timber preservation may be said to date from the invention of the pressure process by John Bethell, an Englishman, in 1838. He placed the timber under a partial vacuum in a horizontal cylinder; then admitted creosote at about 100°F and under a pressure of about 150 lb. per square inch. Only seasoned

*Extract from Wyckoff Pipe and Creosoting Company's Handbook.

^oProceedings of American Society of Civil Engineers, Volume 4.

timber could be treated by this process. This is practically the method used in creosoting at present, except that the timber is first steamed to remove the sap from the cells.

In 1846, Pain introduced the method of steaming previous to the injection of the preservative,* but this was little used until in 1870, 1872 and 1877, Hayford patented a process for using steam before treating. He forced steam into the cylinder containing the wood, until a pressure of 30 to 40 lb. per square inch was reached. When the wood was thoroughly heated, the steam and vapors were driven off and replaced by a vacuum for several hours. Then boiling creosote was injected for several hours. The theory of the steaming is that the timber is heated until part of the sap in the interior of the stick turns to steam which forces out the remainder of the fluid matter with the aid of the vacuum. If all timber could be thoroughly air-seasoned, this would not be necessary, but this is difficult and expensive to do, since it entails high interest charges. The usual procedure at present is to partially air-season and finish the process by steaming.

Although the invention of the steaming process made the preserving methods easier and more reliable, there was no great interest taken in the subject until 1880. At that time there had been only two commercial plants established in the United States, one at Lowell, Massachusetts in 1848, and one in Mississippi in 1874. Railroads had done considerable experimenting, but with widely varying results. A committee was appointed in 1880 by the American Society of Civil Engineers to investigate results in America

*O. Chanute - Municipal Engineering, October 1907.

and Europe. Octave Chamute was chairman of this committee and was known until his death in 1910, as one of the foremost authorities in this country on this subject. The report of the committee in 1885 showed that some very efficient results had been achieved by the processes then in use, and caused many engineers and corporations to awake to the benefits to be derived from their use. But progress was slow due to the low cost of timber and the lack of experience with treated timber. Railroads hesitated to tie up any more capital in maintenance than was absolutely necessary, particularly when the roads were new and money was scarce.

The greatest progress has taken place in the last decade. In 1899 only three railroads were using treated ties and it was estimated that only 10,000,000 ties had been treated up to that time. The total number of ties treated in the year 1910 alone was over 27,500,000.* The number of plants has grown from 16 in 1903, to 30 in 1904 and 78 in 1910.° The plants have grown not only in number but in efficiency, until practically every railroad is now treating at least part of its timber. In 1908, 21.1 per cent of the total number of ties was treated. Not only ties are treated, but bridge timbers, piling, poles, and cross-arms.

The process which has always given the most consistent results is the use of creosote. This has always been the most popular method in Europe due to the lower price of creosote abroad. The experiments on creosoting in this country prior to 1890 contained many failures due to the fact that the creosote was too

*Circular 186, U. S. Forest Service.

°C. P. Winslow, U. S. Forest Service.

expensive to inject in large quantities and the smaller amounts used were insufficient to prevent decay. The higher price of creosote in this country is due to the different utilization of the by-products of its manufacture. Creosote is a product of the distillation of coal-tar. In America, coal-tar is distilled to get soft pitch; in Europe to get aniline dyes. The European process gives a better quality of creosote and is also cheaper, so that in 1909, 73 per cent* of the creosote used in this country was imported.

The high cost and good preservative qualities of creosote have caused a great deal of experimenting to be done, with the object of making it less expensive. There are two general methods of injecting creosote at present, namely, the full-cell and empty-cell. The full-cell is the old process and is carried on practically as originated by Bethell and Hayford. It is commonly known as the Bethell process.

The empty-cell process is patented and is a comparatively recent development. The two most important methods of applying this process are known by the names of the inventors, Rueping and Lowry. "The theory of the Rueping process is first to subject the material to an air pressure of from 65 to 75 lb. per sq. in. Without releasing this pressure, the cylinder is then filled with creosote, which is forced into the timbers with the pressure varying from 100 to 175 lb. per sq. in., according to the nature of the material. The pressure is then released, the creosote run off and a vacuum

*C. P. Winslow, Proceedings of the Engineers Society of Western Pennsylvania. December 1910.

applied to the charge. This release of pressure is said to permit the expansion of the compressed air forced into the timber during the preliminary stage, with a corresponding expulsion of the surplus or free oil. This method, first practiced in Europe, is now used extensively by the Atchison, Topeka and Sante Fe R. R. Company at their treating plant in Texas."* The Lowry process is practically the same, except that the preliminary air pressure is omitted, it being assumed that the air in the timber will be sufficiently compressed by the entrance of the preservative. The theory of these processes is, that it is only necessary to coat the cell walls with creosote and that creosote left inside the cell is wasted. Therefore this surplus preservative is withdrawn.

The empty-cell process illustrates one of the greatest difficulties in wood preservation, i.e., the great length of time required to test a new method. This process has given good results for the few years during which it has been tried, but we do not yet know whether it will prove efficient for a longer period. Engineers at present seem to think that the empty-cell process given sufficient absorption for ties and structural timber, but that the full-cell process gives much better protection against marine borers.

It is unfortunate that creosote is so expensive, as it is usually conceded to give better results than any other preservative. It is the only preparation which successfully withstands the attacks of the teredo. A treatment of 16 to 24 lb. per cu. ft. injected by the Bethell process, has been found to make piling last

*C. P. Winslow, U. S. Forest Service.

practically forever as the creosote does not leach out. Eight to ten lb. per cu. ft. will make ties not protected from mechanical wear, last 15 to 19 years.* A creosoted pine telephone pole near Norfolk, Virginia, is in good condition after 18 years service. It may be seen then, that preservation by creosote is a success, providing it can be shown to be economical at present prices.

The process which stands next to creosoting in age and present importance is the zinc-chloride or Burnettizing method. It was first patented by Sir Joseph Burnett in 1838, the same year that Bethell received his patent for the creosoting process. At first the wood was simply steeped in zinc-chloride, but later the Bethell method of using pressure was adapted to it. It was introduced in America in 1850. There were a number of failures at first, due to the fact that attempts were made to treat unseasoned timber. This gave only a light surface penetration and the sap on the inside caused decay, although the surface appeared sound. However, where the timber was seasoned and the work well done, very good results were attained. In one instance, ties laid on a horse railroad in Cambridge, Massachusetts, in 1855, were in good condition in 1883.^o In England, where timber was imported from long distances, giving plenty of time for seasoning, good results were obtained. When the steaming process was invented, the chief objection to the Burnettizing process was done away with, as the necessary seasoning could then be done in a few hours. Mr. Chanute, however, who used this process almost entirely in his plants,

*Report of Committee on Wood Preservation. American Railway Engineering and Maintenance of Way Association. 1909.

^oAmerican Society of Civil Engineers. Vol. 4.

insisted on a certain amount of preliminary seasoning, stating that good results could not be obtained with green timber.

In some early experiments carried on by the Philadelphia, Wilmington and Baltimore R. R., a 5 or 6 per cent saturated solution was used. The result was that the ties were so brittle that they cracked during unloading. On the other hand, a weak solution has been used in some cases and the chemical leached out after a time and the ties decayed. Experience has shown that a* two and one-half to three per cent solution gives the best results. The leaching out is prevented by variations of the process known as the zinc-creosote and zinc-tannin treatments which will be mentioned later.

Zinc-chloride is used only because it is much cheaper than creosote, in first cost. It is not reliable for structural timber since a strong solution causes the wood to become brittle. It has been used extensively for cross-ties, but is not a success in wet climates due to the leaching out of the salt. Although the first cost of creosote treatment is about twice that of the zinc-chloride process, the number of cross-ties treated by the zinc-chloride process in the period 1907 - 1910, was only 89 per cent of those treated with creosote.° In 1910 out of the approximately 100,000,000 cu. ft. of material treated with creosote and zinc-chloride, more than half was treated with creosote.°

A treatment which is being used to a large extent at present is known as the ^{zinc-}creosote method. There are good reasons for combining these two preservatives. Experience has shown that

*C. P. Winslow, U. S. Forest Service.

°Circular No. 186, U. S. Forest Service.

timber treated with zinc-chloride decays first on the surface, due to leaching out of the salt; and that timber treated with creosote decays first in the heart wood, due to imperfect penetration of the preservative. Evidently a combination of the two methods ought to give ideal results.

By the Allardyce method of using zinc-chloride and creosote, the timber is first air-seasoned for two or three months, and then Burnettized and afterward impregnated with two or three pounds of creosote per cubic foot. Obviously, these three processes make the method quite expensive.

An improved process has been invented by Mr. Card, one of the pioneers in this subject. It is difficult to combine the preservatives and inject them at the same time due to the differences in their specific gravities. "Mr. Card has apparently overcome this by means of a centrifugal pump, the suction of which is attached to the top, and the discharge to the bottom of the treating retort. This is operated through the impregnating period, thereby keeping the preservatives well agitated and in emulsion."* This process is used by the Chicago, Burlington and Quincy., Chicago, Milwaukee and St. Paul and the Baltimore and Ohio railroads in treating ties, and seems to give good results.

The processes which have been described, viz., the creosote, zinc-chloride, and zinc-creosote, are the ones generally accepted at present as being the most reliable and economical. Many other substances and methods have been tried but have failed to stand the test of time.

There have been a number of inventions made to make the

* C. P. Winslow, U. S. Forest Service.

zinc-chloride treatment more effective. The first one which was reasonably successful was that of Wellhouse, patented about 1879. This is usually known as the zinc-tannin process and "consists of impregnating the wood fibres with a hot solution containing about one-half pound of dry zinc-chloride plus one-half per cent of glue or gelatine per cubic foot of wood, then following with a second solution containing one-half percent of tannic acid."* It is claimed that the tannin on coming in contact with the hot glue forms a leathery substance which prevents the zinc-chloride from leaching out.

This method has been used quite extensively for a number of years and has given reasonably good satisfaction. There are conflicting opinions on the efficacy of this treatment as well as all of the others. It is claimed that the glue is liable to decay exactly as is the sap which has been drawn from the wood. It is expensive, since it requires three injections. For this reason it was discontinued by the Atchison, Topeka and Sante Fe R. R. after being used for thirteen years, and is little employed at present by any road.

A method which has been invented in the last few years is known as the Vulcanizing process and consists in the injection of live steam for several hours. It is claimed that this coagulates the albumen in the cells and renders them proof against the fungi. This process has not yet been thoroughly tested but some authorities say that live steam has no preservative effect and is likely to decrease the strength of the timber.

There have been a number of experiments, particularly those

*C. P. Winslow, U. S. Forest Service.

of the Atchison, Topeka and Santa Fe Ry. Company and the National Railway of Mexico, on the use of crude petroleum as a preservative. The crude oil has no antiseptic qualities but simply prevents the admission of air. The oil used is from the Bakersfield pool and has an asphaltic base. It is injected under pressure. The method is claimed to be a success but sufficient time has not elapsed to prove this. In one instance, pine ties treated with crude oil and laid in Texas in 1902 were in good condition in 1909. Untreated ties last only from 1 1/2 to 3 years in this region.*

The above descriptions include the most important processes which use pressure in a closed cylinder. These processes all require an expensive fixed plant. This often necessitates high freight charges in transporting timber from the forest to the plant and then out to the point where it is to be used. A non-pressure process, usually known as the open-tank, has been developed in late years to cut down this expense. This is by no means a new method. The first timber preserving ever done was by steeping in chemicals. This was later improved by Seeley about 1870. He heated timber in a vat of creosote to 212° to 300°, thus driving out much of the sap and changing the rest to steam. He then drew off the hot creosote and replaced it with cold. This condensed the steam in the cells, forming a vacuum and the oil was forced in by atmospheric pressure. This principle is used at present to preserve poles, mine timber, cross-arms, and other materials which do not need the deeper penetration of the pressure process. The absorption is easily controlled by the lengths of the hot and cold baths.

*C. P. Winslow, U. S. Forest Service.

Two methods are used at present in applying this process, viz., the single tank and double tank. The single tank method is practically as given above, the timber remaining stationary and the oil being changed. In the double tank method there are two tanks, one filled with hot and the other with cold oil. The timber is immersed in the hot oil and then moved by a derrick to the cold oil. This is more expensive to operate but the process is continuous, while the single tank can only be charged at intervals.

While the open tank process is often used with very crude apparatus with good results, the best results have been obtained where it was possible to build a large horizontal cylinder and run the timbers in on trucks or "buggies" as they are called. This is the method used in the pressure plants and is the most economical method for handling large quantities. A non-pressure plant of this kind costs only one-third as much as a pressure plant of the same capacity.* The Forest Service recommends a low pressure cylinder which will withstand a maximum pressure of 70 lb. per sq. in. as the most desirable type for treating poles and like materials. This type costs but little more than the non-pressure plant and gives better control and more uniform results.

The open tank method is especially adapted to treating the butts of poles. The butt usually decays at the ground level, long before any other portion is affected. By treating this part only, it may be made to last as long as the rest of the pole. One of the best woods for this form of treatment is loblolly pine,

*W. F. Sherfesees - U. S. Forest Service.

Bul. 84, Forest Service, U. S. Dept. of Agriculture.

PLATE I.



FIG. 1.—TREATING WHITE CEDAR BY BRUSH METHOD.



FIG. 2.—TREATING CHESTNUT POLES BY OPEN-TANK METHOD.



FIG. 1.—CROSS-SECTION OF WESTERN RED CEDAR POLE BUTT, 10 INCHES IN DIAMETER, SHOWING PENETRATION OF CREOSOTE; OPEN-TANK TREATMENT.

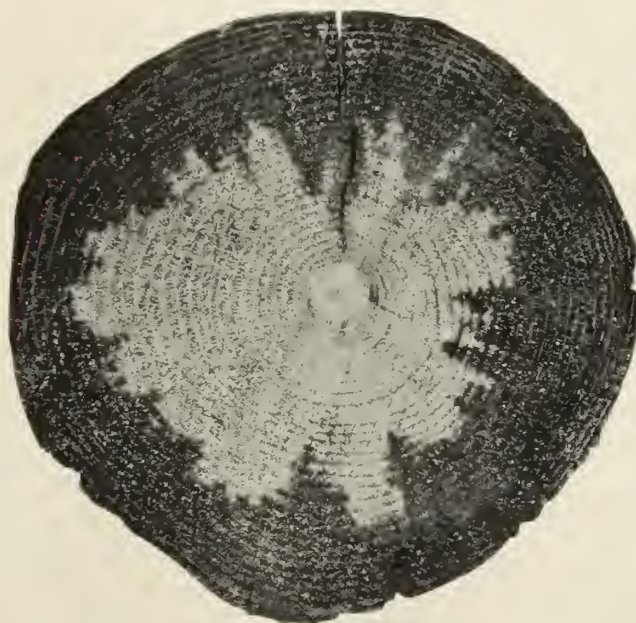


FIG. 2.—CROSS-SECTION OF WESTERN YELLOW PINE POLE BUTT, 14 INCHES IN DIAMETER, SHOWING PENETRATION OF CREOSOTE; OPEN-TANK TREATMENT.

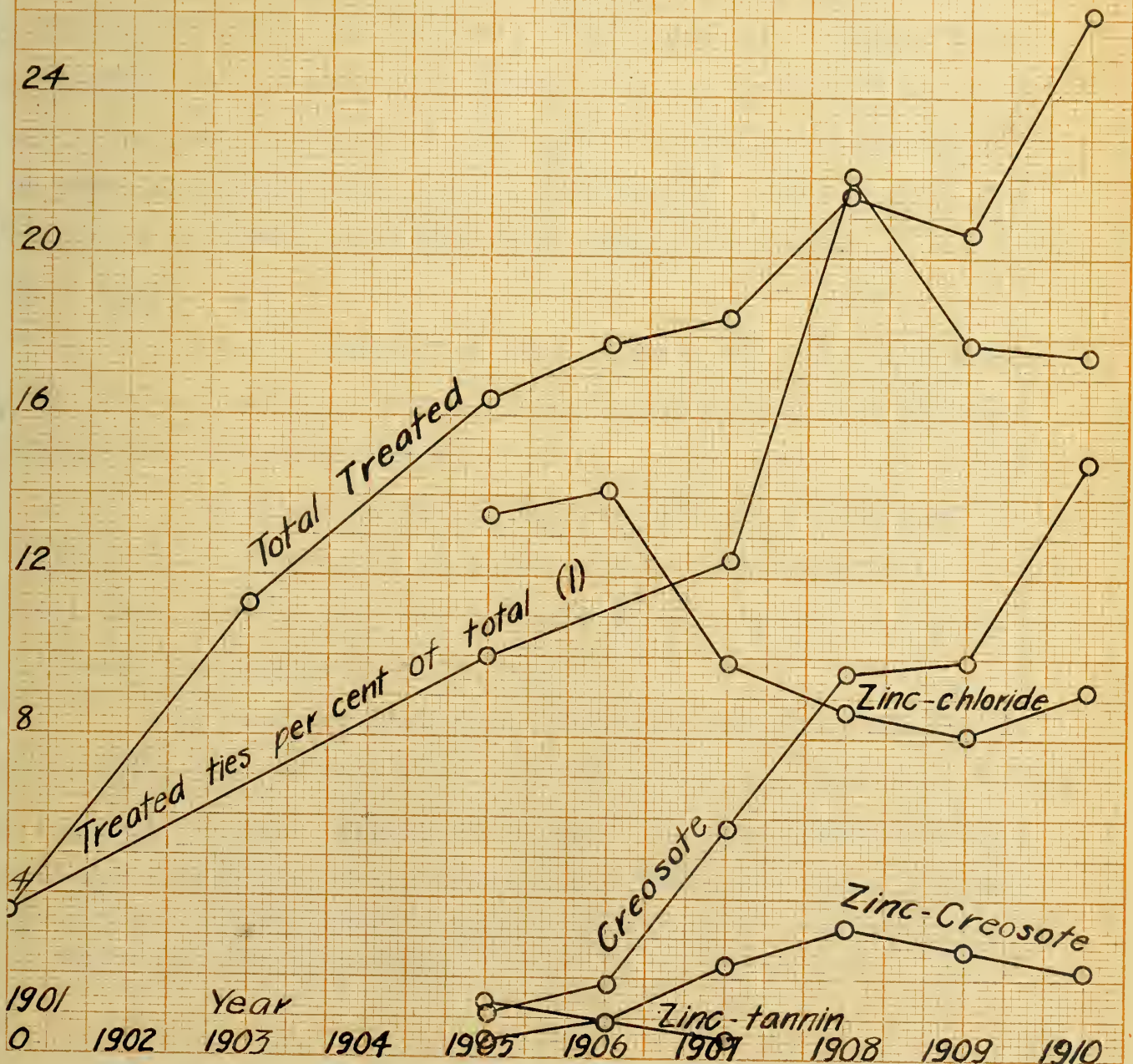
which is used to a large extent for poles in the South. It is not durable unless preserved but as it is easily seasoned, it may be treated at small expense and gives a very serviceable pole. "A penetration of 2 inches in seasoned poles may be obtained, with an absorption of from 8 to 12 pounds of creosote per cubic foot." The plate shows a cross-section of a pole which had received "a treatment of 10 lb. per cu. ft. and showed an average penetration of 1 3/4 inches." This treatment is especially popular on the Pacific coast for western red cedar and lodge-pole pine.

There are a number of patented preparations on the market at present which are designed to be applied with a brush. One which is being used quite largely is a mixture of creosote and zinc-chloride and is known as ^{avenarius} carbolineum. Creosote has also been applied with a brush. This method increases the life of timber but cannot give nearly so good results as the open tank process. It is useful where it is not possible to erect a treating plant of any kind.

Graphs Showing Development of Processes for Treating Ties

Number of ties treated annually
Millions

28 Curve (1) - Per cent



STRENGTH OF TREATED TIMBER.

One phase of the subject of timber preservation which must not escape the attention of the engineer, is the strength of treated timber. Professor W. K. Hatt of Purdue University has made a number of experiments along this line which have been published by the U. S. Forest Service.* The conclusions from his tests on loblolly pine are as follows: (P. 21, Circular 39)

"(1) A high degree of steaming is injurious to wood in strength and spike-holding power. The degree of steaming at which pronounced harm results will depend upon the quality of the wood and its degree of seasoning, and upon the pressure (temperature) of steam and the duration of its application. For loblolly pine the limit of safety is certainly 30 pounds for 4 hours, or 20 pounds for 6 hours.

(2) The presence of zinc chloride will not weaken wood under static loading, although the indications are that the wood becomes brittle under impact.

(3) The presence of creosote will not weaken wood of itself. Since apparently it is present only in the openings of the cells, and does not get into the cell walls, its action can only be to retard the seasoning of the wood."

It has long been known that zinc-chloride causes brittleness and for this reason it has never been used for treating structural timbers. Before the proper amount of chemical to be used was determined, there were several instances where ties were

*Circular 39, Forest Service.

so brittle that they were broken in unloading. In using creosote the only danger is from scorching the wood while steaming it, some tests showing greater strength after treating.

There are a number of conflicting opinions as to the effect of steaming and treating on the spike-holding power of ties. Professor Hatt's tests show that steaming loblobby pine for four hours at less than thirty pounds pressure increases the holding power, while steaming for more than four hours decreases it. He has also conducted experiments with timber treated with crude oil and finds that there is considerable diminution in the spike-holding power with this treatment. In general, it may be said that with skilled manipulation of the processes used at present, the reduction in strength and spike-holding power will never be an argument against the use of treated timber.

COST ANALYSIS.

Preservation of timber effects a saving in two ways; first by increasing the life of the material and thereby lowering the annual expense, second, by decreasing the cost of replacement. In the early part of the last century, when timber was plentiful, the second factor was usually the more important; at present both must be considered. An analysis of available cost data for ties, piling, poles and mine-timbers will be given, paying attention to these two items.

The question of a dependable tie-supply is one which is agitating the minds of all railway maintenance of way officials at this time. It will soon be impossible to get white oak, which has long been considered the most durable wood for ties. An Eastern road was said to be offering 85¢ for white oak ties in 1904 but could not get the order filled.* The problem to be solved then is: will it pay to treat inferior woods and if so, what are the relative advantages of each form of treatment?

Table I was compiled by Professor Gellert Alleman of the U. S. Forest Service for figuring the relative costs of ties. The ordinary annual charge formula is used, $A = \frac{.Or \times c \times (1.Or)^n}{(1.Or)^n - 1}$

in which the following symbols are used:

c = original cost of tie.

n = life of tie in years.

A = annual payment with compound interest, which, if placed aside, will amount to sufficient to replace (at cost of c) the tie at the end of n years.

*American Railway Engineering and Maintenance of Way Assn., 1909.

r = rate of interest on initial cost.

For renewals (Table Ib) the initial cost drops out and the formula reduces to $A' = \frac{c' \times .Or}{(1.Or)^{n-1}}$ in which c' is the cost of

renewal and A' is the annual charge against such renewal.

Table II was compiled by the author using assumptions as to the cost of track fastenings and laying ties, and life of white oak ties published in 1906 by W. C. Cushing, Chief Engineer of Maintenance of Way of the Pennsylvania Lines. Prices may be somewhat higher at present. The prices of ties are those for the year 1909 given in the 1911 report of the American Railway Engineering and Maintenance of Way Association. There has been little change since that time. The average price of all ties for the years 1907 - 1910 is about \$.50, so the analysis given for red-oak ties may also be taken as the average. There are so many variables in such a tabulation that the results can only be taken as comparative.

The table shows that, under the given assumptions, treated ties are in every case cheaper than untreated ties of the same kind of timber and also cheaper than white oak ties costing \$.85. At the prices used it does not pay to use screw spikes and tie-plates to increase the mechanical life of the tie. It is acknowledged that a large per cent of treated ties wear out by mechanical abrasion rather than by decay, so that if a form of screw spike and tie plate which is cheaper can be invented, wood preservation will be a much more efficient investment. The 1911 report of the American Railway Engineering and Maintenance of Way Association estimates that tie-plates alone will increase the life of ties

TABLE Ia - SHOWING ANNUAL CHARGE AGAINST TIE.

The Interest On The Original Cost is Compounded at 4 Per Cent.

LIFE OF TIE, IN YEARS.

ORIGINAL COST OF TIE.	3	4	5	6	7	8	9	10	11
20 cents	Cents 7.21	Cents 5.51	Cents 4.50	Cents 3.82	Cents 3.33	Cents 2.97	Cents 2.69	Cents 2.47	Cents 2.28
25 cents	9.01	6.87	5.62	4.77	4.17	3.71	3.37	3.08	2.85
30 cents	10.81	8.26	6.74	5.72	5.00	4.46	4.04	3.70	3.43
35 cents	12.61	9.64	7.87	6.68	5.83	5.20	4.71	4.32	4.00
40 cents	14.41	11.02	8.99	7.63	6.66	5.94	5.38	4.93	4.57
45 cents	16.21	12.39	10.11	8.59	7.50	6.69	6.06	5.55	5.14
50 cents	18.01	13.77	11.24	9.54	8.33	7.43	6.73	6.17	5.71
55 cents	19.81	15.15	12.36	10.49	9.16	8.17	7.40	6.79	6.28
60 cents	21.61	16.52	13.49	11.45	10.00	8.91	8.08	7.40	6.85
65 cents	23.42	17.90	14.61	12.40	10.83	9.66	8.75	8.02	7.42
70 cents	25.22	19.28	15.73	13.36	11.66	10.40	9.42	8.64	7.99
75 cents	27.02	20.66	16.86	14.31	12.50	11.14	10.10	9.25	8.56
80 cents	28.82	22.03	17.98	15.26	13.33	11.89	10.77	9.87	9.14
85 cents	30.62	23.41	19.11	16.22	14.16	12.63	11.44	10.49	9.71
90 cents	32.42	24.79	20.23	17.17	14.99	13.37	12.11	11.10	10.28
95 cents	34.22	26.16	21.35	18.13	15.83	14.12	12.79	11.72	10.85
100 cents	36.02	27.54	22.48	19.08	16.66	14.86	13.46	12.33	11.42
For each additional 5 cents to the cost add	1.801	1.377	1.124	0.954	0.833	0.743	0.673	0.617	0.571

TABLE Ib - SHOWING ANNUAL CHARGE AGAINST TIE.

The Interest On Cost of Relaying is Compounded At 4 Per Cent.

TIME OF RELAYING, IN YEARS.

COST OF RELAYING	3	4	5	6	7	8	9	10	11
	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents
10 cents	3.20	2.35	1.85	1.51	1.27	1.08	.95	.83	.74
15 cents	4.80	3.53	2.77	2.26	1.90	1.62	1.42	1.25	1.11
20 cents	6.41	4.71	3.69	3.02	2.53	2.16	1.89	1.66	1.48
25 cents	8.01	5.89	4.62	3.77	3.17	2.71	2.36	2.08	1.85
For each additional cent, add .....	.320	.235	.185	.151	.127	.108	.095	.083	.074

TABLE Ib (Contd) - SHOWING ANNUAL CHARGE AGAINST TIE.

The Interest On Cost of Relaying is Compounded At 4 Per Cent.

TIME OF RELAYING, IN YEARS.

COST OF RELAYING	TIME OF RELAYING, IN YEARS.									
	12	13	14	15	16	17	18	19	20	
10 cents	Cents .67	Cents .60	Cents .55	Cents .50	Cents .46	Cents .42	Cents .39	Cents .36	Cents .34	
15 cents	1.00	.90	.82	.75	.69	.63	.58	.54	.50	
20 cents	1.33	1.20	1.09	1.00	.92	.84	.78	.72	.67	
25 cents	1.66	1.50	1.37	1.25	1.15	1.06	.97	.90	.84	
For each additional cent, add ...	.067	.060	.055	.050	.046	.042	.039	.036	.034	

(Note: Costs given in cents.)

TABLE II.

	UNTREATED WOODS				TREATED WOODS					
	Without Tie Plates				Without Tie Plates			With Tie Plates and Screw Spikes		
	White Oak	Hemlock	Red Oak		Hemlock	Red Oak	Creosote 10 lb. per cu.ft.	Hemlock	Red Oak	With Plates Only
Treatment used					ZnCl	Zn-Creosote		ZnCl	Zn-Creosote	
Assumed life of tie in years	10.	5	6	10	12	17	15	17	20	14
Assumed cost of tie delivered and foreign freight	85.0	31	50.0	31.0	50.0	50	31.0	31.0	50	50
Cost of switching and putting in tie	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Cost of 4 track spikes	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Cost of 4 wood screws	6.4	6.4	6.4	6.4	6.4	6.4	6.4	--	--	6.4
Cost of 4 helical linings	--	--	--	--	--	--	--	15.0	15.0	--
Cost of 2 tie plates	--	--	--	--	--	--	--	3.0	3.0	--
Cost of application of fastenings	--	--	--	--	--	--	--	32.0	32.0	32.0
Total cost of laying tie	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>
Cost of treating tie	28.4	28.4	28.4	28.4	28.4	28.4	28.4	81.0	81.0	60.4
Total cost of tie in track	113.4	59.1	78.4	74.4	105.0	133.4	133.4	112.0	158.0	137.4
Annual charge for tie	13.98	13.49	14.96	9.25	11.19	10.96	12.00	10.08	11.52	13.05
Annual charge for relaying tie	<u>2.36</u>	<u>5.36</u>	<u>4.28</u>	<u>3.66</u>	<u>2.89</u>	<u>1.19</u>	<u>1.42</u>	<u>4.05</u>	<u>2.75</u>	<u>3.32</u>
Total annual charge	16.34	18.85	19.24	12.91	14.09	12.15	13.42	14.13	14.58	16.37

from one to three years. Taking the average as two years, thus making the life of a red oak tie treated with zinc-creosote 14 years, the table shows that tie-plates do not pay under the assumptions used. However, screw spikes and tie-plates are used almost universally in Europe, where a heavy injection of creosote is employed giving a long life. Baltic pine ties laid in this way are said to last 30 years. American railways are loath to invest such a large amount of money in ties, so the cheaper forms of treatment and rail-fastenings are being used.

The U. S. Forest Service and other timber authorities advocate the use of "S" irons to prevent checking. These are made of strap iron bent in the form of a letter "S". If the ties are inspected before being laid and S irons driven into the ends of all ties that show signs of checking, many ties are saved from early decay.

There is less difficulty in figuring the economic value of preservative treatment for piling than for cross-ties. Untreated pine piles are destroyed by the teredo in the Gulf of Mexico in from one to three years while the life of piling of the same material treated with from 16 to 24 pounds of creosote per cubic foot is 20 to 25 years,*and there are many instances where it has lasted 30 years. Treatment is also beneficial in fresh water where pine piles costing \$.20 to \$.25 per foot will rot off at the water line in about seven years while a creosoted pile which now costs about \$.50 per foot has given a life of at least twenty-eight years on the

*American Railway Engineering and Maintenance of Way Assn., 1909.

Louisville and Nashville Railroad.* The following table compiled by data given by Mr. A. F. Robinson of the Sante Fe° shows the value of preservative treatment:

No.	Class of Bridge	Treatment	Life Yrs.	Average Annual Cost, Dollars.
1	Open deck pile	Untreated	8	2.12
2	Open deck pile	Piles, caps and sway-braces creosoted, remainder, un- treated	Treated parts, 24, Untreated, 8.	1.99
3	Ballasted deck pile	Creosoted	24	1.82

In this, as in all cost analysis of this kind, the fact must be borne in mind that there is every reason to believe that timber will continue to increase in value, so that the present worth figured a few years from now will greatly exceed that computed from present prices. For instance, the type of bridge listed as number 3 in the table, was built at an average cost of \$16.00 per foot of track up to 1904, but in 1911 some of these bridges cost as high as \$22.00 per foot and \$19.00 was taken as the average. The cost of structures built of untreated timbers is also increasing at a rapid rate, due to the fact that longer freight hauls are now necessary, and the softer woods which must be used have a shorter life.

The cost of treating piling and bridge timber is greater per cubic foot than that of ties, due to the greater difficulty in handling and the deeper penetration and longer time

*A. F. Robinson, American Railway Engineering and Maintenance of Way Assn., 1911.

of treatment necessary. A cost of \$20.00 has been given for a 60-foot pine pile and \$37.00 for a 75-foot pile with an 18-inch butt.* This will vary with location, timber used, and other factors. Mr. A. F. Robinson gives \$40.00 per M feet B.M. as the cost of treating bridge timbers on the Sante Fe. Structural timber has been treated by the open tank process at a cost of \$10.00 per M feet B.M.° This method is not as reliable as the pressure process but often gives as good results as are necessary.

The ratio of treated telephone and telegraph poles to the entire number of purchases has been steadily increasing during the past few years. The proportion has grown from one-eighth in 1907 to one-sixth in 1909. Probably most of this treatment was done by the open tank process. The Forest Service** estimates that a double-tank plant for the butt-treatment of poles may be built for from \$4,000 to \$5,000, and that the average cost of treatment exclusive of preservatives will be about \$.45 per pole. A low pressure plant may be built for \$10,000 which will treat the entire pole. However, it is usually considered necessary to treat only the butt, as most poles decay at the ground line. Where the poles can be well-seasoned, the open-tank process gives good penetration in the sap-wood and this is all that is necessary. The treatment of poles, particularly by the open-tank process, is of so recent origin that it is difficult to give figures as to its financial value. "Records of the German Postal and Telegraph Department covering fifty-two years, show an average life of 20.6

*Professor Gellert Alleman in Proceedings of Engineer's Club of Philadelphia, vol. 24, 1907.

°American Railway Bridge and Building Association, 1908.

**Bulletin 84, U. S. Forest Service.

TABLE III. - ESTIMATED FINANCIAL SAVING DUE TO CREOSOTE TREATMENT OF POLES.

Computations are made on a basis of 5 per cent interest.

Species	Diameter. In.	Length. Ft.	Character of treatment	Amount of creosote per pole. Lb.	Estimated cost of treatment Dolls.	Estimated cost of pole in place Dolls.	Estimated life in yrs.	Annual cost Dolls.	Annual saving to treatment Dolls.
Chestnut.....	7	30	(Untreated.....)	.....	.....	6.00	10	0.77	.....
			(Brush treatment)	7	0.20	6.20	13	.66	0.11
			(Open-tank treatment..)	25	.75	6.75	16	.62	.15
Southern white cedar.	7	30	(Untreated.....)	.....	.....	5.00	10	.65	.....
			(Brush treatment.....)	5	.20	5.20	13	.55	.10
			(Open-tank treatment..)	40	.95	5.95	18	.51	.14
Northern white cedar.	7	30	(Untreated.....)	.....	.....	7.00	14	.71	.....
			(Brush treatment.....)	5	.20	7.20	17	.64	.07
			(Open-tank treatment..)	50	1.05	8.05	22	.61	.10
Western red cedar....	8	40	(Untreated.....)	.....	.....	9.50	10	1.23	.....
			(Brush treatment.....)	8	.30	9.80	13	1.04	.19
			(Open-tank treatment..)	40	1.35	10.85	20	.87	.36
Western yellow pine..	8	40	(Untreated.....)	.....	.....	8.00	3	2.94	.....
			(Brush treatment.....)	6	.30	8.30	5	1.92	1.02
			(Open-tank treatment..)	60	1.90	9.90	20	.79	2.15
Lodgepole pine.....	7	35	(Untreated.....)	.....	.....	7.00	5	1.62	.....
			(Open-tank treatment..)	40	1.25	8.25	20	.66	.96
			(Untreated.....)	.....	.....	2.50	3	.92	.....
Loblolly pine.....	6	35	(Entire pole, open (tank or pressure....	200	2.45	4.95	20	.40	.52

years for creosoted poles."^a Table III from Bulletin 84 of the U. S. Forest Service gives estimates as to the financial saving and the following cost analysis is given in the same bulletin.

"A 7-inch 35-foot lodgepole pine pole is worth \$3 f.o.b. cars in the mountain region of Colorado. Recently an Idaho cedar pole of the same size could be obtained in the same region for \$5.25, including transportation. A butt treatment for the pine pole will cost \$1.25, making the total cost of the treated pole \$4.25. Let it be assumed, however, that owing to local freights the first cost of the untreated cedar and the treated pine at the point of use will be the same, namely, \$5.25. Setting, which is very costly in a mountainous region, may be figured at \$4, making the cost of either pole in place \$9.25. Assuming that the untreated cedar will last in this region fifteen years, and the treated pine twenty years, the annual costs of the two poles become \$0.89 and \$0.74, respectively, or an annual saving of \$0.15 in favor of the pine pole. At the rate of forty poles to the mile this will amount to a saving of \$6 each year for each mile of line in operation.

"In the vicinity of Fresno, Cal., a 40-foot cedar pole brought from Washington costs \$8, while a native pine pole may be obtained for \$5. A heavy butt treatment of creosote may be given the the latter for \$1.90, making the total cost \$6.90. Allowing \$3 for setting in either case, the respective costs of the poles in line are \$11 and \$9.90. Pole users in this locality estimate the life of cedar at ten years, while it is believed that the treated pine will last twenty years. On this basis the respective annual costs of the

^aArchiv für Post und Telegraphie, Nr.16, Berlin, August 1905.



FIG. 2.—CREOSOTED LOBLOLLY PINE POLE AFTER EIGHTEEN YEARS' SERVICE. NO SIGN OF DECAY.



FIG. 1.—UNTREATED POLE OF SOUTHERN WHITE CEDAR (CHAMÆCYPARIS THYOIDES) AFTER FOUR YEARS' SERVICE.

two poles are \$1.42 and \$0.79, an annual saving of \$0.63 on every native treated pole in use. In this case there is a saving even in the first cost, and a relatively greater saving when the lives of the two poles are compared."

Cross-arms for telegraph, telephone and electric lines are also being treated by the open-tank process and to a lesser extent by the pressure method. It has been found to be more economical to use cheap woods such as loblolly pine treated with creosote, rather than more expensive woods untreated. Little data is available as to comparative costs. The Bangor Railway and Electric Company (Maine) treated spruce cross-arms at an average cost of \$.12 3/4 for a 10 foot cross-arm. Treatment was considered economical at this price.°

Although large quantities of timber are used in the mines of this country, amounting to 200,000,000 cu. ft. in 1905, it is only very recently that there has been much interest taken in the preservation of mine timber. Extensive experiments have been carried on by the U. S. Forest Service in the mines of the Philadelphia and Reading Coal and Iron Company since 1906 to determine the value of treatment. These tests were so successful that this company has decided to treat all timber which is not liable to be broken or worn away in a short time. Since the timbers are exposed to a large amount of moisture the zinc-chloride treatment is not considered practicable and an open tank treatment with creosote is usually used. The cost for an absorption of 10 pounds per cubic foot is \$.11 per cubic foot.* The Consolidated Coal Company of

*Circular No. 111 - U. S. Forest Service.

°American Railway Bridge and Building Association Report, 1908.

Saginaw, Michigan, have treated mine-timbers by the open tank process for several years. Mr. Randall, the general manager, states, "The expense of retimbering under the union scale of wages in the mines is very large, and therefore, we feel it is economical to treat the timber. Timbers treated have never shown any signs of rot so far, (after five years) while untreated timber has to be replaced in from one to two years."* From these indications it is believed that the next few years will see a great development in the treatment of mine timbers.

CONCLUSION.

This review of the development of timber preservation shows that while there have been comparatively few new processes invented during the last few years, great strides have been made in the commercial development of the existing methods. It is now generally conceded that preservative treatment is a successful means of preventing decay and that it pays. Only the comparatively large first cost now prevents its universal use and such cheap and efficient methods as the open tank process are rapidly removing this obstacle. In view of the diminishing supply of timber, it is only reasonable to expect that the next decade will see greater progress along this line than ever before.

*American Railway Bridge and Building Association Report, 1908.





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